TECHNICAL GUIDANCE DOCUMENT

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

BIOREMEDIATION:

A General Outline

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Notice

The Technology Evaluation Group (TEG) completed this evaluation of Bioremediation based on professional expertise and review of items listed in the "References" section of this document. The criteria for performing the evaluation are generally described in the IDEM OLQ technical memorandum, Submittal Guidance for Evaluation of Remediation Technologies.

Background

This is not a comprehensive text, but rather a short overview with terms, and notes as to applications and general effectiveness. Bioremediation is a form of remediation resulting from microbial action. Normal soils are replete with a huge range of naturally occurring microbes, which interact in a complex micro-ecosystem. Although concentrated hydrocarbons (free product) and solvents may kill almost all microbes, some species will feed on and degrade many less concentrated contaminants. Bioremediation is the most active force in the natural attenuation of contamination. Active bioremediation methods involve some man-made attempt at improving the speed or efficiency of natural bioremediation. This is usually by adding microbes, nutrients, chemicals, etc.

Applied correctly and on the proper type-site, some additives can markedly improve the speed of bioremediation. Additives specified in a corrective action plan should be carefully evaluated to see if they would be a cost- and time-effective improvement.

Corrective action plans using bioremediation need to be evaluated on a site-by-site basis because microbial action is controlled by site conditions and what will work at one site may not at another. However, some general statements may be made about the various methods, which can be divided into ex-situ and in-situ bioremediation.

EX-SITU BIOREMEDIATION

Ex-situ bioremediation is bioremediation taking place after the contaminated soil is excavated and removed. It may be expensive, mostly due to the cost of digging and hauling the soil. It disrupts the site and requires a good deal of room. Ex-situ bioremediation is, however, usually far more successful than in-situ bioremediation. The act of excavation breaks up the natural soil packing and dramatically increases permeability and porosity. Air is naturally added as the soil is churned up, and most of the effects of soil conditions and chemistry are controllable. This alone is usually enough to greatly stimulate microbial action.

Land Farming relies on excavation and mechanical stimulation for remediation. The soils are spread out in about 18-inch lifts, and tilled occasionally to aerate the soil and break up clumps so microbes can work more effectively, and volatiles escape. It is usually successful and inexpensive for clean-ups of the lighter hydrocarbons, but does require much open space. Diesel contamination in clay soil may not clean up appreciably, especially in thick lifts.

Biocells (or biomounds) are soil treatment units, which are used to make remediation faster, and use less space than land farming. Most cells are covered to control moisture and temperature, and some utilize an air delivery system to increase oxygen. Nutrients are often added. These often work quite well. Minnesota has developed an extremely efficient biocell, which uses sheep manure for nutrients, and the only other additives are air and straw!

Bioreactors are large treatment tanks filled with microbial solutions, which are used to clean water, soil, or air. These are quite specialized for each application, and require much experience and engineering, but can work well.

IN-SITU BIOREMEDIATION

In-situ refers to in-place bioremediation, (aerobic or anaerobic) without excavation. In-situ bioremediation is far more complex, difficult to control, and less successful than ex-situ methods. Many additives and bioremediation systems are on the market, but success usually depends on site conditions, and it is extremely difficult or impossible on many sites for a delivery system to reach all affected areas, particularly in fine-grained or highly stratified soils (United States Environmental Protection Agency (USEPA) 2000). Extra monitoring requirements are usually necessary to ensure that remediation is progressing.

Natural attenuation, as mentioned above, is usually occurring at all sites, and is often the main limiting factor in contaminant plume movement. If natural attenuation is the sole method of remediation at a site, the USEPA and the State of Indiana refer to this as monitored natural attenuation, because thorough site characterization and continued monitoring is mandatory. Due to inherent site conditions (soil heterogeneity, permeability, pH, temperature, oxygen levels, other soil and groundwater chemistry, and type and amount of contamination); natural attenuation may be exceedingly slow.

Active in-situ bioremediation methods are attempts to overcome one or more of the limiting factors.

Biostimulation is the addition of something in an attempt to increase the activity of the naturally occurring microbial population. This can range from the addition of nutrients to the increase of oxygen. This category includes bio-venting (or biosparging), the pumping of air through the soil and/or groundwater to increase oxygen. It also includes chemical additives such as oxygen, and nitrogen or fertilizer additions.

Some forms of biostimulation work quite well. All are quite dependent on site conditions; none can be applied successfully at every site. Corrective action plans must be complete and detailed as to the product, amounts, application methods, monitoring, reapplication needs, and final testing. To just list a product name, without detailing how it will be used, will not be adequate; more information is needed.

Bioaugmentation is the adding of additional microbial cultures. Unless a site has been completely sterilized, there are usually microbial cultures already in place (see below for exceptions), with a complex interaction of species. The activities of one species may provide nutrients for another. Some species often live on others, or their waste streams. Some species will degrade hydrocarbons much better at higher contaminant levels, while other microbes function at lower levels. A whole suite of cultures is usually needed to ensure a complete progression to cleanup. The absence of one or two critical species can dramatically slow site remediation.

It is difficult to add microbial cultures. Microbes injected into a well rarely extend beyond the well sand pack, a foot, or so into the formation. Adding extra microbes from the outside, even from cultures taken from the site, overburden the site population and change species proportions. In many cases, the lab-cultured microbes cannot survive in the foreign and possibly hostile environment (USEPA 1994). Also, microbes may prefer to eat other microbes rather than contaminants, so adding more microbes can lead to the destruction of some beneficial indigenous species. Actual USEPA field tests have shown that bioaugmentation can more than double remediation time for aerobic degradation of hydrocarbons, compared to the control section of the site, which was not treated.

For the reasons noted above, the USEPA does not recommend using bioaugmentation on sites which already have a viable microbial population (USEPA 1992) and also states "It is essential that independently-reviewed data be examined before employing a commercially- marketed microbial supplement"(USEPA 1994). Although microbial cultures have been applied on numerous sites, IDEM Staff has not been able to validate a case in Indiana where in-situ bioaugmentation for hydrocarbon compounds has proven effective, and agrees with the USEPA.

One form of bioaugmentation which may be successful is the use of specialty microbes for MTBE remediation. The indigenous microbes present at most sites often have a limited capacity for the ingestion of MTBE, so cultivated microbes may be more successful. Good results have been claimed for the use of in-ground treatment cells, or "reactive barriers." A zone of higher permeability soil is created (usually by trenching), and microbes, nutrients, and oxygen are supplied to the zone by an active injection system. This is much different than just injecting microbes across the site, and is more similar to an ex-situ treatment cell. Problems still exist in that microbes seem to prefer BTEX to MTBE, so MTBE may not be degraded until all BTEX is gone, which may allow time for the MTBE to migrate through the treatment zone. No pilot studies have been reported for Indiana sites, and the application is still regarded as experimental at this time.

Bioaugmentation by adding dehalogenating bacteria is a common method for remediation of chlorinated sites (USEPA 2004). The microbes needed to completely degrade chlorinated compounds may not be present on all sites, and samples should be tested to see if useful microbes are present in sufficient quantities. The Interstate Technology & Regulatory Council (ITRC) states that dehalogenating microbes are only present about half the time (ITRC 2004). Pilot studies in Indiana have reported much improved remediation with the inoculation of additional cultures, combined with the addition of an aquifer 'conditioner' to provide food and aid in keeping the site anaerobic.

Conclusion

February 16, 2010. TEG Staff evaluated the results of many more bioremediation sites in Indiana. The most successful were combined remediation systems, where bioremediation was done on a site along with another form of remediation, such as in-situ chemical oxidation, pump & treat, or source removal. Bioremediation by itself often did not take a site all the way to closure, in a practical timeframe. Biostimulation was the most common and most effective form of bioremediation, by itself, or in combination.

After evaluation of three more years of data, TEG Staff has not seen evidence, that bioaugmentation is effective (except for the limited conditions noted above).

Further Information

If you have any additional information regarding this technology or any questions about the evaluation, please contact the Technical Evaluation Group at (317) 232-8866 or by e-mail at lsteadha@idem.in.gov. This technical guidance document will be updated periodically or if new information is acquired.

References

ITRC, 2004. Accelerated Bioremediation of Chlorinated Solvents, Training Course Workbook.

USEPA 2004. Technologies For Treating MtBE and Other Fuel Oxygenates. USEPA 542-R-04-009.

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USEPA 1992. A Citizen's Guide to Using Indigenous and Exogenous Microorganisms in Bioremediation. USEPA/542/F-92/009.